Parametric study on shape of safety injection tank

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1. Introduction

When an accident occurs in a reactor, passive tanks with various types are used to supply emergency cooling water to a reactor vessel. A core makeup tank using a gravitational head of water subsequent to making a pressure balance between the reactor and tank and a nitrogen pressurized safety injection tank are used in the passive loop type reactors such as AP600, AP1000 and so on. A nitrogen pressurized safety injection tank has been typically designed to quickly inject a high flow rate of coolant in a safe manner when the internal pressure of the reactor vessel is rapidly decreased due to a large break loss of coolant accident, and a core makeup tank has been designed to safely inject into the reactor at high pressure for the early stages of the accident.

In the present study, we investigate a pressure balanced type of safety injection tank, which is designed to inject cooling water into the reactor at medium or low pressure when an accident occurs. Figure 1 illustrates the schematic of the pressure balanced type of safety injection tank. The pressure balance type of safety injection tank is designed to have proper height difference from the injection nozzle on the reactor vessel, and it is connected to the reactor vessel through the injection line and pressure balance line. The pressure balanced type of safety injection tank is isolated from the reactor vessel by the isolation valves on the pressure balance line and the check valves on the injection line during normal operation. By opening the isolation valves on the pressure balance line, the cooling water in the safety injection tank can be injected into the reactor by the gravitational head when the steam from the reactor coolant system is injected into the safety injection tank through the pressure balance line and the internal pressure of the reactor coolant system and safety injection tank reaches the equilibrium state. In the present study, a parametric study has been performed to understand the injection characteristics of the balance type of safety injection tank.

2. Thermal hydraulic model of safety injection tank

The water level and injection flow rate of the balance type of safety injection tank are derived using the thermal hydraulic model. The mass conservation, Bernoulli equation and Darcy formula are as follows [1],

$$\rho_L A_{SIT} \frac{dL}{dt} = -\dot{m}_{inj} \tag{1}$$

$$\frac{P_{FS}}{\rho_L g} + z_{FS} + \frac{v_{FS}^2}{2g} = \frac{P_E}{\rho_L g} + z_E + \frac{v_E^2}{2g} + h_L \tag{2}$$

$$h_L = \frac{v_E^2}{2g}\left(\frac{fl}{d} + K\right)_E = \frac{v_E^2}{2g}\Pi_E \tag{3}$$

Where ρ_L is the water density, A_{SIT} is the cross section area of the safety injection tank, $L(t)$ is the water level of the safety injection tank, L_E is the height difference between injection nozzle and the bottom of the safety injection tank, $\dot{m}_{inj}$ is the injection flow rate, v_E is the velocity of the injection line, f is the friction coefficient of the injection line, Π_E is the pressure loss coefficient of the injection line. The water level of the safety injection tank $L(t)$ and injection flow rate of the safety injection tank $\dot{m}_{inj}$ are obtained by using Eq. (1), (2) and (3).

$$L(t) = \left(\left(L_0 + L_E\right)^{1/2} - \frac{C}{2}t\right)^2 - L_E \tag{4}$$

$$\dot{m}_{inj}(t) = \rho_L A_{SIT} C\left(\left(L_0 + L_E\right)^{1/2} - \frac{C}{2}t\right) \tag{5}$$

Where, $C = A_E / A_{SIT}\left(2g/1+\Pi_E\right)^{1/2}$, $A_{SIT} = \pi/4\left(D_{SIT}\right)^2$, L_0 is the initial water level of the safety injection tank.

3. Results and discussion

A parametric study has been performed to observe the effect of tank shape on injection flow rate of the safety injection tank, varying the safety injection tank diameter and total height. During the sensitivity analysis, total internal volume of safety injection tank is constant at 100 m^3 and the water volume in the safety injection tank is assumed as 80 m^3. The main parameters for the sensitivity analysis of the safety injection tank are summarized in Table I. D_{SIT} and L_{SIT} are the diameter and the total height of the safety injection tank, respectively. The water density is $\rho_L = 1000$ kg/m^3, the height difference between injection nozzle and the bottom of the safety injection tank is L_E = 5 m and the pressure loss coefficient of the injection line is used at Π_E =5000 for present sensitivity analysis.

Figure 2 shows time variations of the injection flow rate and water level in the safety injection tank with four different shape of the tank. The initial injection flow rate of the safety injection tank increased with the tank total height. The depletion time of the safety injection tank is decreased with increasing the tank total height. For L_{SIT} = 9.3, 11.6, 15.1, 21.2 m, the depletion time of the safety injection tank is 54.2, 52.0, 49.2, 45.4 hours, respectively. At 37 hours, the injection flow rate for four different shapes of the safety injection tank is similar each other, due to similar water level of the safety injection tank at that time. However the reduction rate of the injection flow rate of the safety injection tank is different at 37 hours. The reduction rate of the injection flow rate decreased with the tank diameter, as shown in Fig. 2 and Eq. (5).

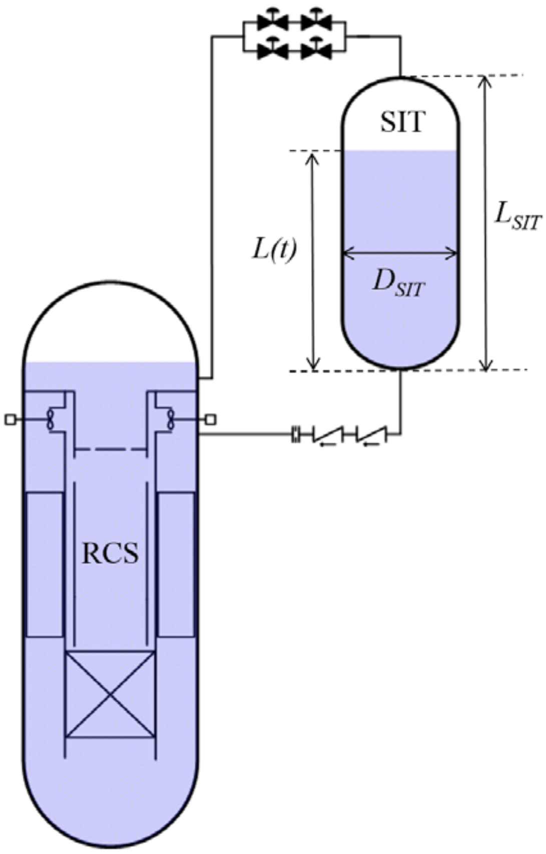


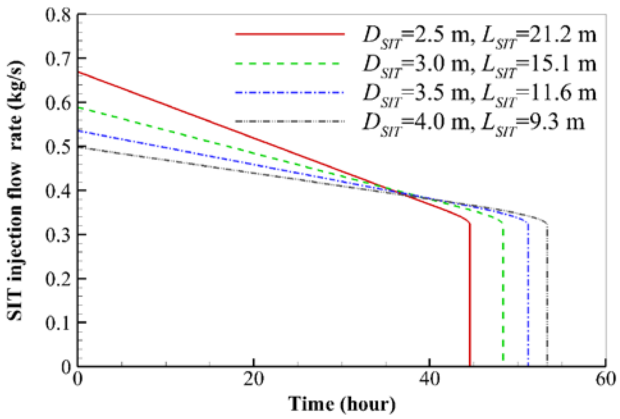
Fig.1. Schematic of a safety injection tank

4. Conclusions

A sensitivity analysis has been performed to investigate the effect of the tank shape on injection flow rate and depletion time of the safety injection tank, changing the safety injection tank diameter and total height. The initial injection flow rate of the safety injection tank increased with the tank total height. The depletion time of the safety injection tank is decreased with increasing the tank total height. The reduction rate of the injection flow rate of the safety injection tank decreased with the tank diameter.

Table I: Parameters for the sensitivity analysis of SIT.

Case	D_{SIT}	L_{SIT}	L_0	V_{SIT}
1	2.5 m	21.2 m	16.7 m	100 m^3
2	3.0 m	15.1 m	11.8 m	100 m^3
3	3.5 m	11.6 m	8.9 m	100 m^3
4	4.0 m	9.3 m	7.0 m	100 m^3



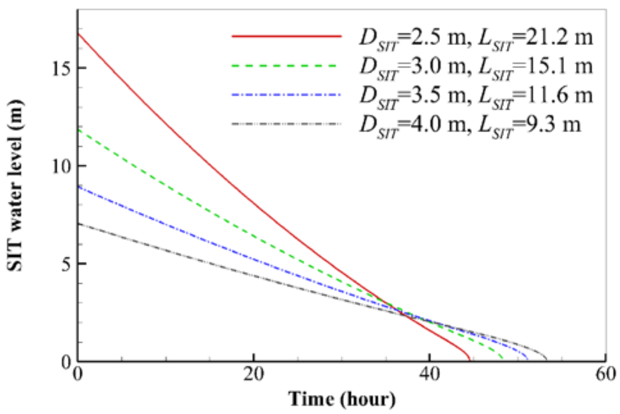


Fig.2. time variation of the injection flow rate and water level of the safety injection tank

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) funded by the Korea government (MIST) (2016M2C6A1930039), in addition to funding from King Abdullah City for Atomic and Renewable Energy, Kingdom of Saudi Arabia, within the SMART PPE Project.

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